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The Changing Skill Structure of Employment in Canada

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by
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Abstract

This paper presents a short synthesis of recent findings on the changing skill structure of employment and on some of the sources of change emerging from Human Resources Development Canada's research programme on the theme of "Skills Requirements in the Knowledge-Based Economy." It addresses three main questions:

- How has the skill structure of employment evolved in Canada?
- What has been the role of technological change in the changing structure of employment?
- Do the skills of the Canadian workforce meet the requirements of the knowledge-based economy?

The bulk of the paper examines the changing structure of employment using an occupational classification scheme that categorizes occupations on the basis of the tasks performed by workers. This approach was originally developed by Wolff and Baumol and adapted for Canada by Marie Lavoie and Richard Roy in the paper "Employment in the Knowledge-Based Economy: A Growth Accounting Exercise for Canada."

Résumé

Ce document présente un bref résumé des constatations récentes sur l'évolution de la structure des compétences de l'emploi ainsi que sur certaines des sources de changement qui ressortent des travaux de recherche de Développement des ressources humaines Canada portant sur les compétences requises dans l'économie axée sur le savoir. Il se penche sur trois grandes questions :

- Comment la structure des compétences de l'emploi a-t-elle évolué au Canada?
- Quel rôle les changements technologiques ont-ils joué dans la structure changeante de l'emploi?
- Les compétences de la main d'oeuvre canadienne répondent-elles aux exigences de l'économie axée sur le savoir?

Le document examine principalement la structure changeante de l'emploi à partir d'une classification des professions établie en fonction des tâches exécutées par les travailleurs. Cette méthode a été mise au point par Wolff et Baumol, et adaptée pour le Canada par Marie Lavoie et Richard Roy, dans l'article intitulé *Employment in the Knowledge-Based Economy: A Growth Accounting Exercise for Canada.*

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The authors wish to thank Marie Lavoie, Ali Béjaoui and Daniel Boothby for their significant contribution and helpful comments.

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1. Introduction

The view that industrialized economies are experiencing a new period of economic development in which knowledge plays an increasing role in the organization and development of economic activities has gained currency in recent decades. While one can claim that all modern economies have been founded on knowledge, some argue that we are now entering an era in which the capacity to accumulate knowledge becomes a *sine qua non* for individuals to access employment and adapt to changing circumstances and, for an economy, to achieve growth (Lavoie and Roy: 1998). In this context, understanding changes in employment patterns, particularly as they relate to changes in skills requirements, has become increasingly central to a better understanding of the labour market implications of the trend towards a more "knowledge-based economy" (KBE).

Technoiogical change, in general, and information and communication technologies (ICTs), in particular, are often considered the main sources of significant labour market change. Like electricity and steam power, ICTs are general-purpose technologies (GPTs) which are very pervasive and, according to Lipsey (1996), bring with them deep structural adjustments (DSAs).

While these new technologies are a catalyst of change in employment patterns, they are only one of the myriad of interconnected factors that are contributing to the labour market reality we are presently witnessing. Suffice it to mention the recent intensification of international competition, which has led to changes in trading patterns and important employment adjustments, institutional change in the labour market, changes in organizational behaviour, government policies, and so on. All of these elements contribute to modify employment patterns (OECD: 1996a).

The purpose of this paper is to present a short synthesis of recent findings on the changing skill structure of employment and on some of the sources of change emerging from Human Resources Development Canada's (HRDC) research programme on the theme of *Skills Requirements in the Knowledge-based Economy*. It will address three main questions:

- How has the skill structure of employment evolved in Canada?
- What has been the role of technological change in the changing structure of employment?

- Do the skills of the Canadian workforce meet the requirements of the knowledge-based economy?

The bulk of the paper examines the changing structure of employment using an occupational classification scheme that categorizes occupations on the basis of the tasks performed by workers. This approach was originally developed by Wolff and Baumol and adapted for Canada by Lavoie and Roy (1998).

Section 2 presents the rationale for examining the occupational structure rather than the industrial structure for understanding the employment implications of a KBE and describes the classification scheme. The third section examines the broad employment trends by type of worker over the period 1971-91 and the skills required of these occupations along several dimensions. Section 4 presents some evidence on the possible sources of employment changes and in particular the impact of computerization on the demand for the different types of workers. In section 5, we examine several indicators to assess whether Canada's population possesses the skills to meet the requirements of the new economy. Finally, the conclusion summarises briefly some of the main findings, identifies knowledge gaps and outlines plans for future research.

2. A Knowledge-Based Occupational Classification Scheme

In a recent study, Marie Lavoie and Richard Roy (1998) present some of the basic facts regarding the broad employment trends in the knowledge-based economy (KBE). The study provides a sense of the magnitude of the trend toward a KBE and its significance in terms of labour force composition. This section discusses the advantages using occupations as opposed to industrial sectors for analyzing employment trends and describes their classification of occupations and its rationale in the context of a KBE.

Contrary to what has been done in most Canadian studies, Lavoie and Roy (1998) do not define the KBE on the basis of industrial activities. Instead, the authors argue that the basic tasks performed by workers are more useful for understanding the skills required by the KBE and the evolving structure of employment. In particular, an industrial classification approach cannot properly capture the effects of workers' displacement due to organizational changes within firms.

The increasing rate of "contracting out" since the mid-1970s provides a good example of the potential impact organizational changes in production may have on employment. Taking the business services industry as an example, it has been argued that a significant portion of the employment growth in this sector simply reflects a shift of former internal production activities from other industries. In other words, according to this perspective, the overall composition of production in the economy and, hence, total labour requirements may not have changed much over time. However, based on a classification by industry, one could wrongly conclude that a tremendous growth in business services activity in the economy has occurred and that an increase in the supply of workers appropriate to that industry is needed.[1] Organizational changes in production therefore cannot be entirely understood or identified on the basis of an industrial classification of activities and thus an occupational approach allows for a better understanding of the employment effects of the restructuring within establishments and firms.

The Classification Scheme

It is increasingly recognized that knowledge, as an asset, plays a critical role in the economy, and countries endowed with more knowledge are expected to be more productive. Moreover, there is

[1] This industry is usually classified as knowledge-intensive and requires highly educated workers.

growing evidence across countries which indicates important employment trends emphasizing highly skilled workers. While most studies examining employment trends combine various types of knowledge, Lavoie and Roy (1998) takes into account the differentiated nature of knowledge and assumes that there is some heterogeneity in the potential contribution and productivity level among categories of workers and, especially, among categories of highly-skilled workers.

The classification scheme follows the approach developed by Wolff and Baumol and is based on the reasoning that human production tasks involve dealing with objects, with people, or with symbols, and are directed at producing goods, providing personal services, or generating information. Under this scheme, the labour force is divided into two main categories of workers: information and non-information occupations. Information occupations are further divided into two groups: data and knowledge occupations. The distinction between these two categories of occupations is meaningful in a context where ICTs affect these groups of occupations quite differently.

Data occupations involve the manipulation of symbolic information whereas knowledge occupations involve mainly the generation of ideas or the provision of expert opinions. In other words, data workers – such as most clerical workers and technicians – use, transmit or manipulate information while knowledge workers – such as engineers, scientists or economists – produce knowledge. The broad distinction between these two categories of occupations in a context in which ICTs are highly pervasive is that data occupations involve a relatively large portion of routinized tasks which could be fairly easily replaced or supported by electronic devices while the knowledge category of occupations involves the production of new ideas and requires some level of creativity for which the computer and other technologies could hardly serve as a substitute.

Looking at the non-information category of occupations – services and goods occupations – the same logic could apply in relation to the diffusion of ICTs. Goods occupations are amenable to technological change given the more routinized and, therefore, codifiable nature of the tasks these occupations entail. Conversely, services occupations, which include personal services, are not really codifiable since the tasks are highly tacit. That is, they constitute a group of occupations for which the expertise is mainly built on experience (learning-by-doing) instead of

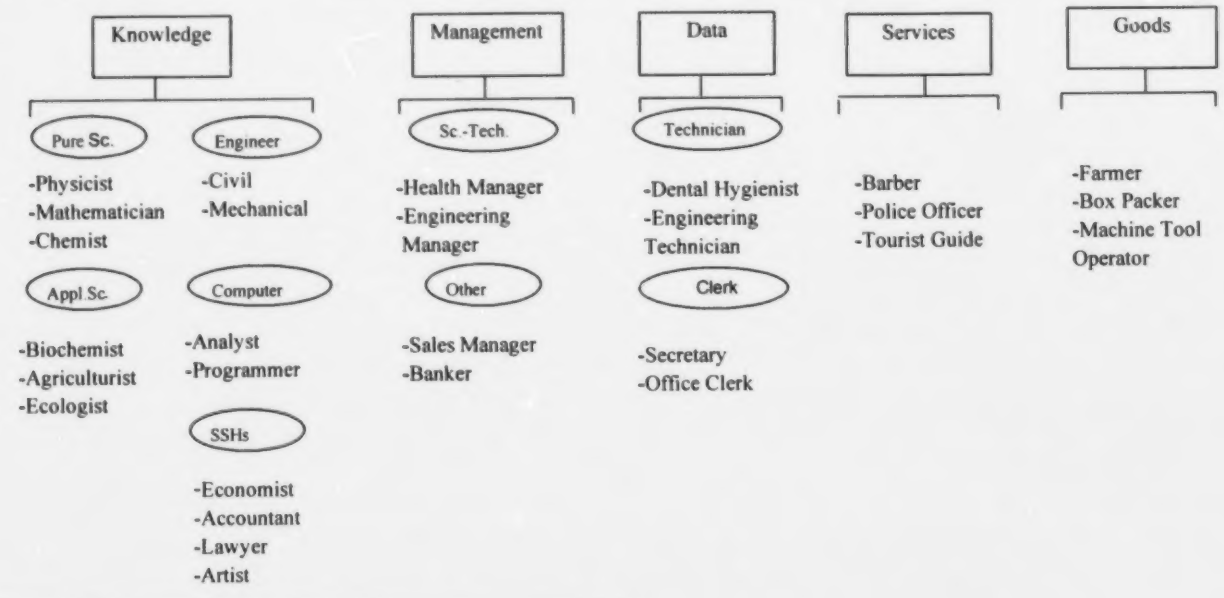
routinized tasks. These distinctions are likely important in the context of technological change as will be discussed in Section 4 below.[2]

The knowledge category of workers has been further divided into 5 sub-categories – pure science, applied science, computer science, engineering and social sciences and humanities (SSH). This division reflects the fact that the knowledge category is not homogeneous in terms of tacit/codified content of tasks as well as in terms of the nature of the know-how involved. Moreover, in relation to technological change, science and technology expertise is at the core of the innovation process and therefore the driving force in the KBE. Disaggregating the knowledge category is thus necessary to better understand the way in which these different bodies of knowledge are linked with scientific and technological change.

The final category of occupations to consider is the management category. Whereas Wolff and Baumol considered this category as a hybrid of the knowledge/data category of occupations, Lavoie and Roy argue that managing requires different skills from those required to perform a knowledge occupation and different skills from the ones on which data occupations rely. In other words, managerial complexity is something different from scientific, technological or social complexity. As a result, the management category is treated separately and is split into two categories – science and technology (S&T) management and other management. The classification scheme is shown in Figure 1.

[2] Distinguishing the nature of knowledge into tacit and codified is fundamental in order to understand the employment effects of technological change. While codified knowledge essentially means that it is easy to transmit and access and is even substitutable, tacit knowledge is not easily transferred from one person to another since it requires a learning-by-doing process to be acquired.

Figure 1
Occupational Classification



Note: Occupational titles included are examples only.

Source: Lavoie and Roy (1998)

3. Occupational Employment Trends and the Skill Requirements of Knowledge Occupations

We now turn to an examination of growth and changes in the composition of employment for each category of workers over the 1971-1996 period based on the classification scheme described above. It will also provide some evidence on the skill requerements for the knowledge category of occupations.

3.1 Employment Trends by Occupational Skills

Table 1 shows employment growth and employment shares by type of worker over the 1971-1996 period. Growth in total employment averaged 2.1 percent per year over this period with major recessions in the early 1980s and 1990s contributing to slower overall employment growth in more recent decades compared to the 1970s. The management category outpaced all other groups of occupations over this period with spectacular growth during the first decade. At 7.6 percent per year, the management category had by far the highest rate of growth over the 1971-1996 period, expanding at nearly four times the pace of total employment and close to twice that of total knowledge occupations (4.1 percent). Knowledge occupations grew the fastest in the 1990s, however, at more than twice the rate of total employment (2.5 vs 1.1 percent per year).

At a disaggregated level, computer science occupations outpaced all other groups of occupations (8.3 percent) except for the S&T management category which grew at about the same rate. While computer science occupations accounted for the same proportion as pure science occupations in 1971, the rate of growth of the former was nearly three times that of the latter during the entire period. This reflected the skill bias towards computer science workers as a result of the proliferation of computer technologies. Interestingly, the SSH group[3] experienced stronger growth than engineering and pure and applied science occupations which are assumed to be at the core of the knowledge-based economy since science and technology activities are increasingly considered the engine of the economy.

[3] The SSH category of occupations – the largest sub-category of the knowledge group – comprises a variety of knowledge expertise. If we subdivide this category, we find that, over time, accountants made up between 40 and 50 percent of the SSH category. Then comes the artistic group which accounted for a little less than a third of the SSHs while legal occupations made up almost 10 percent of the category. Together these three categories of expertise accounted for about 80 to 90 percent of the SSH group between 1971 and 1991 in Canada.

Table 1

Employment by Category of Occupations, 1971-1996

Percent of Total Employment

Categories	1971	1981	1986	1991	1996
Knowledge	**5.3**	**6.3**	**7.1**	**8.0**	**8.5**
Pure Science	0.3	0.3	0.3	0.3	0.4
Applied Science	0.7	0.7	0.8	0.8	0.8
Engineering	1.2	1.3	1.3	1.4	1.4
Computer	0.3	0.6	0.8	1.1	1.3
SSHs	2.8	3.5	3.9	4.3	4.6
Management	**2.7**	**7.0**	**8.3**	**9.7**	**10.0**
Sci.-Tech.	0.2	0.8	0.8	0.9	1.0
Other	2.5	6.2	7.4	8.7	9.1
Data	**36.2**	**37.1**	**36.7**	**37.5**	**36.9**
Services	**14.5**	**13.9**	**15.3**	**15.7**	**16.1**
Goods	**41.3**	**35.7**	**32.6**	**29.1**	**28.5**
Total Employment	***100.0***	***100.0***	***100.0***	***100.0***	***100.0***

Average Annual Rate of Growth (%)

Categories	1971-81	1981-91	1971-91	1981-86	1986-91	1991-96	1971-96
Knowledge	**4.7**	**4.4**	**4.5**	**4.1**	**4.7**	**2.5**	**4.1**
Pure Science	1.9	4.1	3.0	4.0	4.2	2.5	2.9
Applied Science	3.0	3.2	3.1	2.9	3.4	1.1	2.7
Engineering	3.6	3.1	3.4	1.6	4.6	1.4	3.0
Computer	9.5	9.3	9.4	10.4	8.2	4.2	8.3
SSHs	5.2	4.1	4.6	4.1	4.1	2.6	4.2
Management	**13.0**	**5.4**	**9.1**	**5.3**	**5.5**	**1.9**	**7.6**
Sci.-Tech.	17.0	3.5	10.0	2.0	5.1	1.9	8.4
Other	12.6	5.6	9.1	5.7	5.5	1.9	7.6
Data	**3.0**	**2.1**	**2.6**	**1.7**	**2.5**	**0.8**	**2.2**
Services	**2.4**	**3.3**	**2.8**	**3.9**	**2.7**	**1.6**	**2.6**
Goods	**1.3**	**-0.1**	**0.6**	**0.1**	**-0.2**	**0.7**	**0.6**
Total Employment	***2.8***	***2.0***	***2.4***	***1.9***	***2.1***	***1.1***	***2.1***

Note: Census data used for 1971, 1981, 1986 and 1991. Figures for 1996 are based on the L.F.S. data.

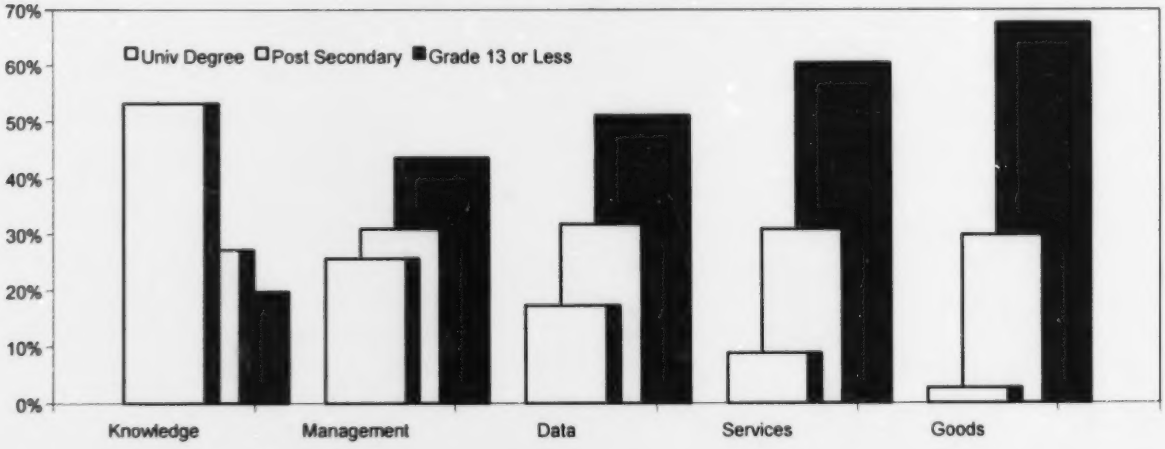
Source: Lavoie and Roy (1998)

While the growth of knowledge occupations has been strong, their overall share of employment remains small. In 1996, knowledge occupations accounted for only 8.5 percent of total employment in Canada, up from 5.1 percent in 1971. On the other hand, their share has generally increased in all major industry groups, including industries normally considered "low-tech." The growth in employment of knowledge workers therefore represents a widespread trend in the Canadian economy.

3.2 Skill Requirements of Knowledge Occupations

Given the pervasiveness of knowledge occupations in the economy, an important question is what are the underlying skill requirements of these fast-growing occupations? As shown in Figure 2, knowledge workers are highly educated. Around 50 percent of have a university degree and another 28 percent have at least some post-secondary qualifications.

Figure 2
Highest Level of Education Attained
Employed, Aged 25 to 44, 1991 Census



Source: Lavoie and Roy (1998)

While education is an important measure of the skills required to perform a job, other dimensions of skills are increasingly being emphasized in the context of the emerging KBE. For example, evidence from HRDC's Essential Skills Project and Sector Studies indicates that literacy requirements of jobs are increasing in many sectors as a result of technological and

organizational change.[4] Literacy skills are also essential to the development of "digital literacy" skills – that is familiarity with computers and networks and the ability to use them. Other dimensions such as problem-solving skills, communication skills, organizational skills and the ability to work in teams are also being increasingly emphasized.

The importance of literacy skills for knowledge work is revealed in a study by Boothby (1999) who uses the results from the International Adult Literacy Survey (IALS) to examine the distribution of literacy levels among the different occupational categories[5] for three types of literacy skills: prose, document and quantitative literacy.[6] These are shown in Figures 3 to 5. In general, workers with the highest literacy level (level 4/5) are concentrated among knowledge, management and data occupations. In contrast, workers with the lowest literacy levels (levels 1 and 2) make up the majority of workers in data manipulation, service, goods and other goods occupations.

With respect to other skill dimensions, a recent study by Béjaoui (1999) examines the basic competencies required by knowledge and management occupations according to five skill types: cognitive skills, authority-management skills, communication skills, fine motor skills and gross motor skills.[7] As shown in Figures 6 to 8, these occupations require significantly more cognitive,

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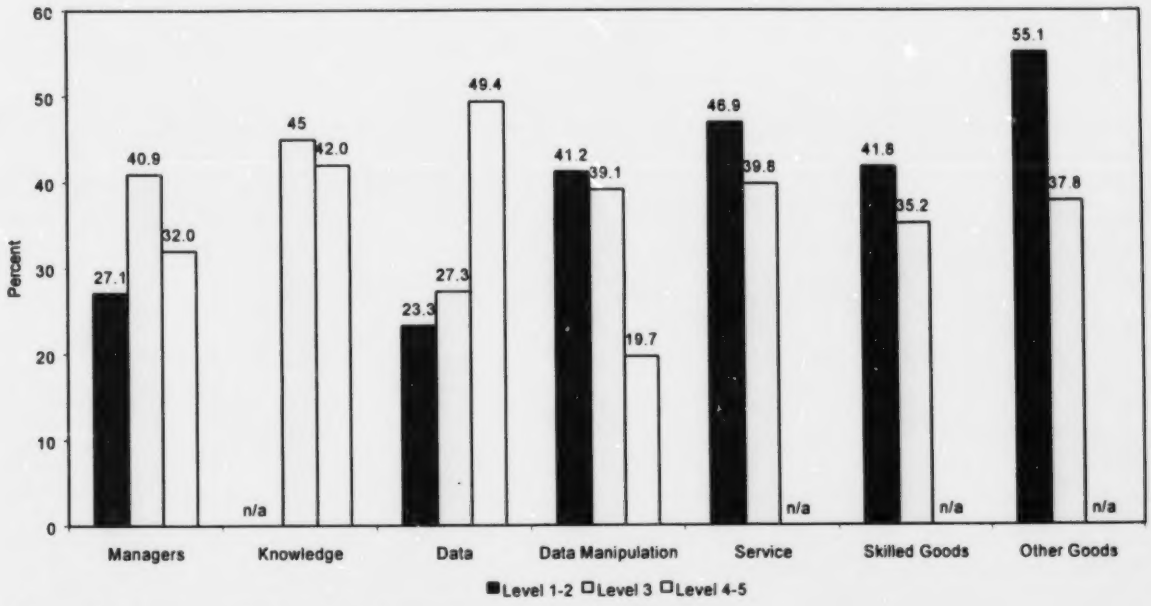
[4] Information on HRDC's Essential Skills Project and Sector Studies can be accessed via Internet at: http://www.hrdc-drhc.gc.ca/hrp/index_e.html.

[5] The occupational classification used by Boothby (1999) is based on the one developed by Lavoie and Roy (1998) but differs from the latter in that the data and goods categories of occupations have been further divided to reflect the fact that each of the original categories contain a wide range of occupations some of which require a high degree of knowledge while the others are mostly routine in nature. As a result the data category is divided into the "data" and "data manipulation" categories and the goods category has been divided into the "skilled goods" and "other goods" categories.

[6] The IALS measured three types of literacy skills. The prose scale refers to the literacy needed to understand and use information from texts including news stories and fiction. The document scale refers to the literacy required to locate and use information contained in various formats such as job applications, maps and tables. The quantitative scale refers to the knowledge and skills required to apply mathematic operations to numbers contained in text such as completing an order form or balancing a checkbook. Level 1 on these scales is the lowest level measured and level 5 is the highest. See OECD (1997) for a guide to the scales and their interpretation.

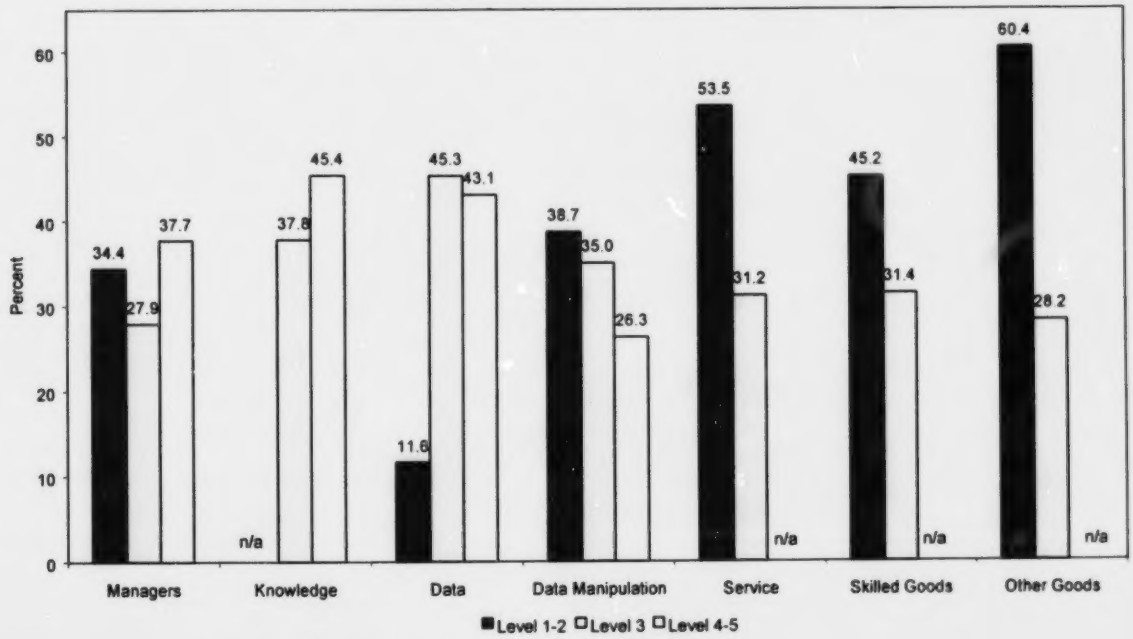
[7] The author uses indexes of the basic competencies required by occupations constructed and averaged a the four-digit level (around 500 occupational groups) by Hunter and Manley (1986) using the Canadian Classification and Dictionary of Occupations which provides direct measures of 43 traits/functions across 6,500 occupations (e.g. complexity of work involving data, people or things; specific vocational preparation; intelligence; scientific work; motor skills; etc.). These features of occupations were then aggregated according to an optimization procedure (LISREL) into the five skill dimensions or basic competencies for each occupation. See Béjaoui (1999) for details.

Figure 3
Prose Literacy Levels by Occupational Category



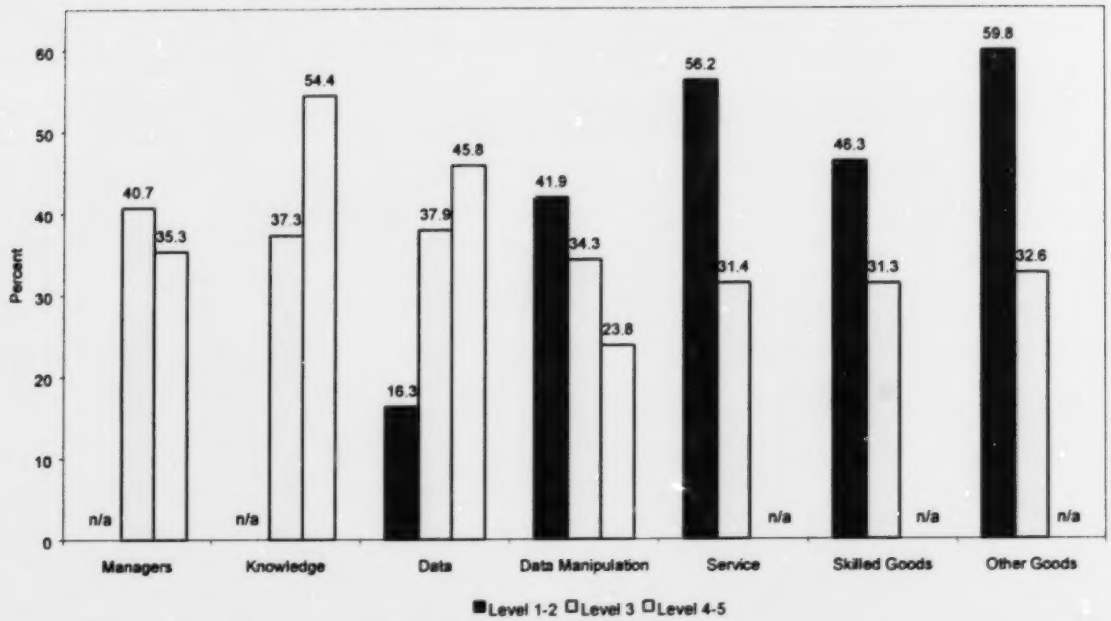
n/a: Percentages omitted due to insufficient sample size
Source: Boothby (1999)

Figure 4
Document Literacy Levels by Occupational Category



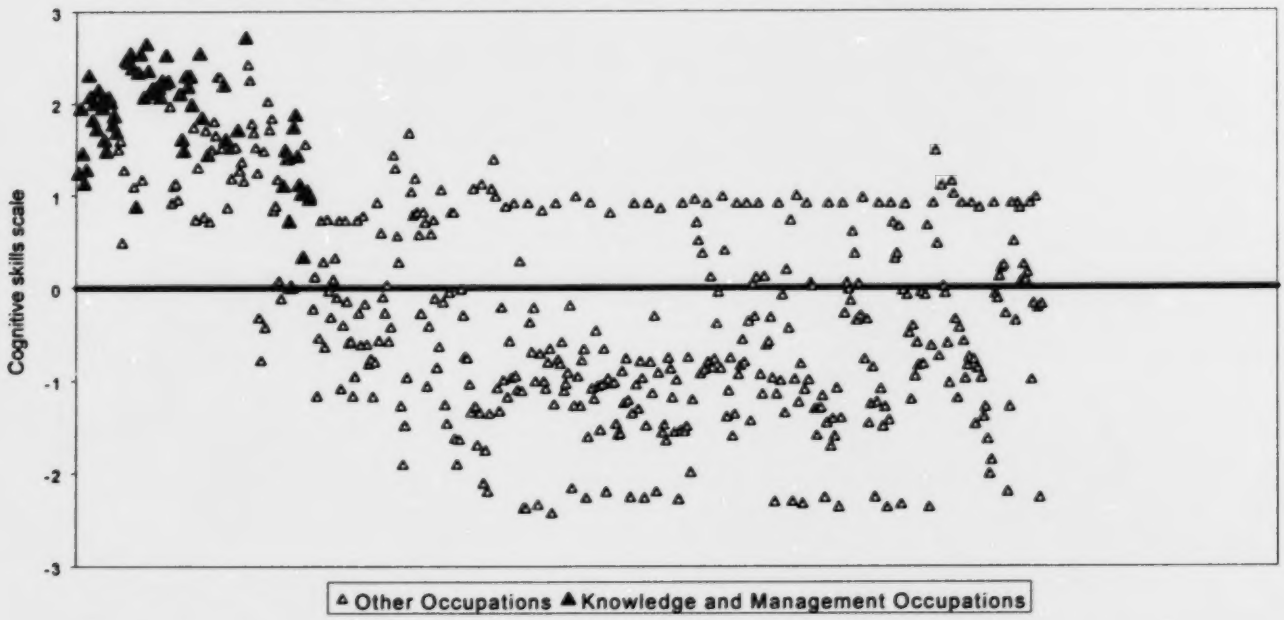
n/a: Percentages omitted due to insufficient sample size
Source: Boothby (1999)

Figure 5
Quantitative Literacy Levels by Occupational Category



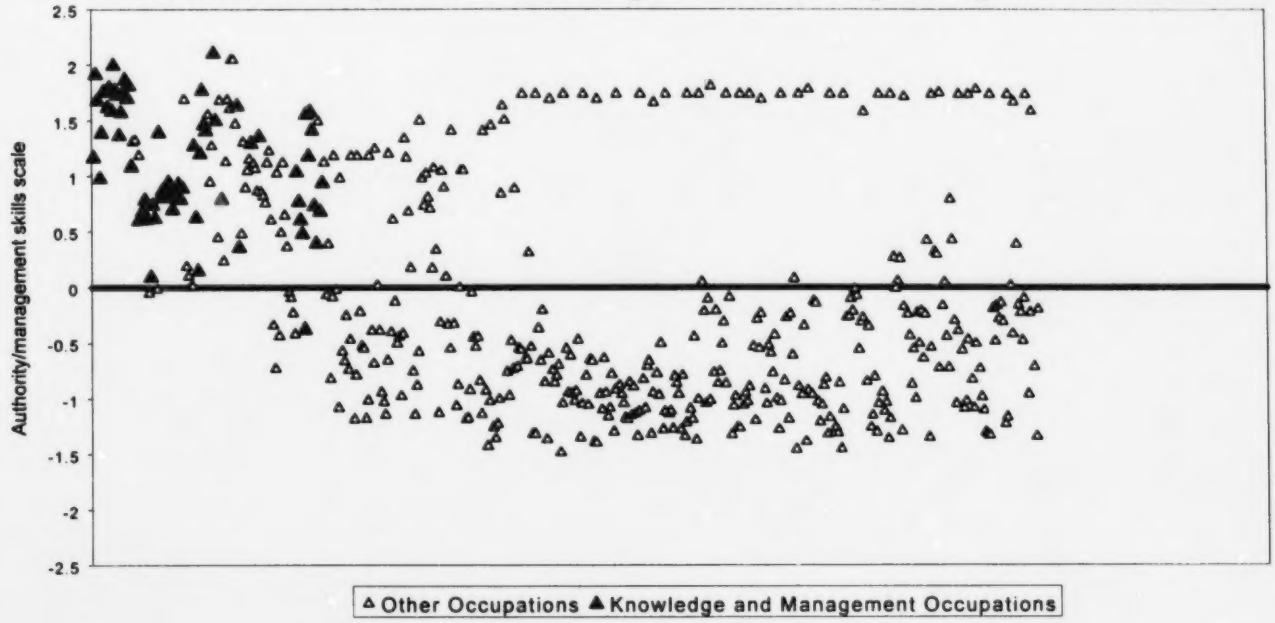
n/a: Percentages omitted due to insufficient sample size
Source: Boothby (1999)

Figure 6
The Distribution of Occupations According to the Cognitive Skills Scale



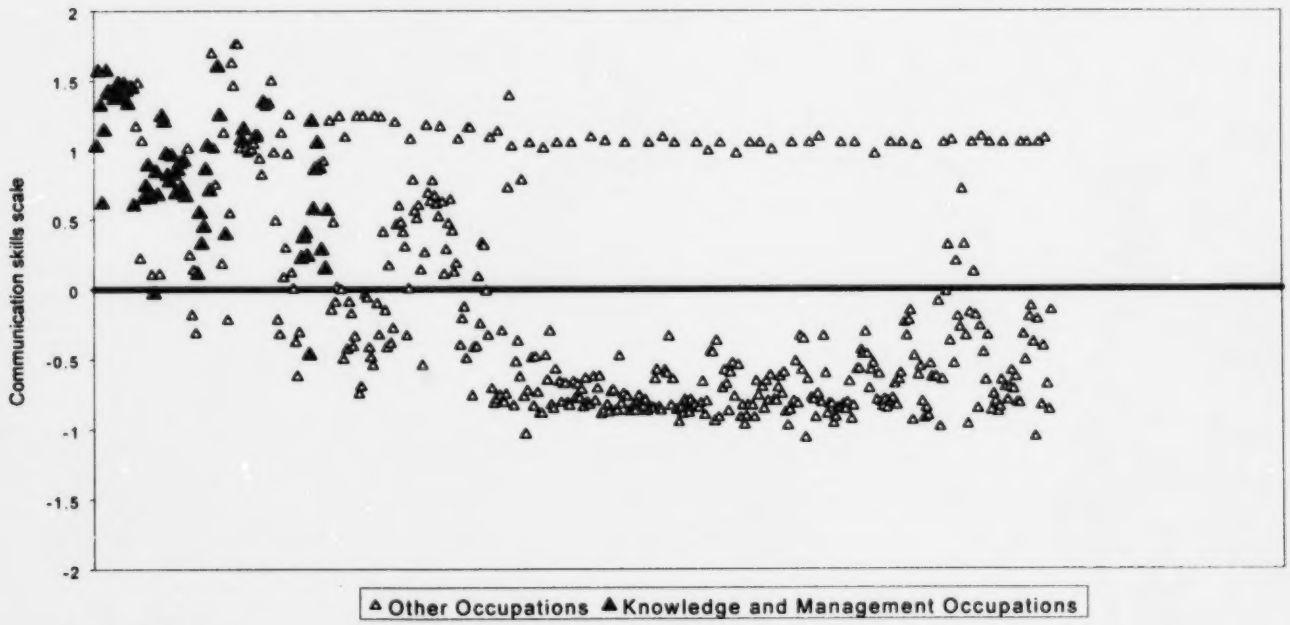
Source: Béjaoui (1999)

Figure 7
Distribution of Occupations According to the Authority/Management Skills Scale



Source: Béjaoui (1999)

Figure 8
Distribution of Occupations According to the Communications Skills Scale



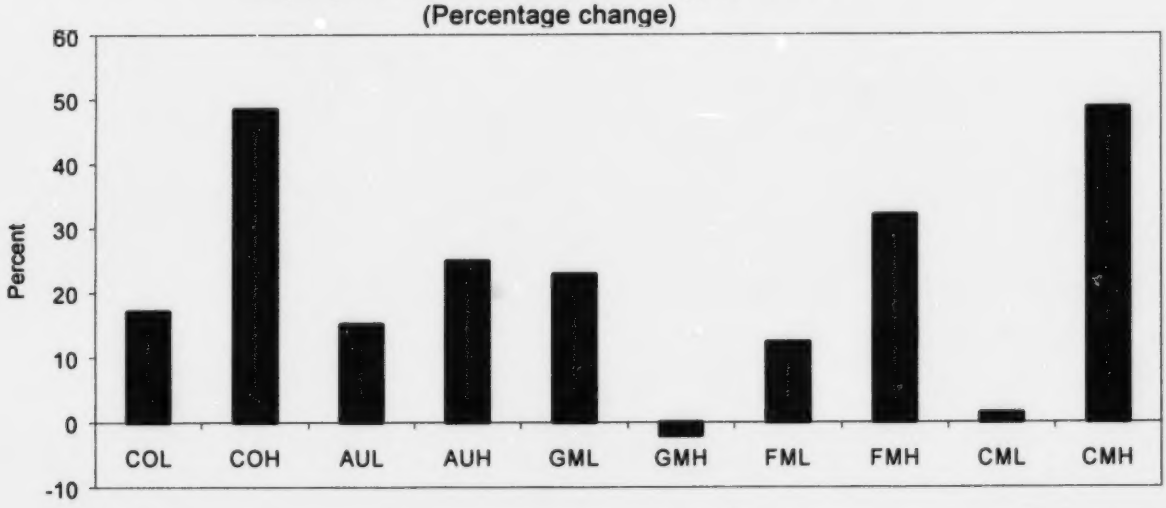
Source: Béjaoui (1999)

authority-management and communication skills than most other occupations.[8] The difference between these and other occupations is particularly striking with respect to cognitive skills.

To get a better picture of the evolution of overall employment in occupations which require different levels of these basic competencies, Figure 9 shows the percentage change in employment in the deciles with the highest and lowest levels of basic competencies required by all occupations. For example, CO_L is the percentage change in employment in the 10 percent of occupations that require the lowest level of cognitive skills, while CO_H is the percentage change in employment in the 10 percent of occupations that require the highest level of cognitive skills.

Between 1981 and 1991, occupations which require high levels of cognitive and communication skills registered the strongest increase in employment. In contrast, employment fell for occupations requiring a high level of gross motor skills. Thus, the competencies underlying knowledge and management work registered the strongest growth. These results are consistent with the observed employment patterns of knowledge and management occupations presented above.

Figure 9
Employment Growth by Skill Type, 1981-91
(Percentage change)



Source: Béjaoui (1999)

[8] The average level of competency required of all occupations for each dimension is equal to zero. This results from the normalization of the latent variables (i.e. traits), which by definition, have no comparable units of measure. For each skill dimension, deviations from the mean are used to compare one occupation to another.

4. Sources of Employment Changes

The preceding section has shown that over the last quarter century or so, the proportion of knowledge workers has grown substantially in the Canadian economy. It was also shown that this phenomenon has generally encompassed all major industry groups and therefore represents a widespread trend in the Canadian economy. Why is this happening?

A number of different factors have been advanced which may explain the occupational employment trends we are observing. The proliferation of technological innovations and their dissemination throughout the economy is certainly a prime candidate. They may have made the organization of production more complex such that businesses may require more and more knowledge workers to operate and thrive in the new world economic order. The fact that the proportion of knowledge workers has grown in all major industry groups certainly suggests that the source of change is systemic. Institutional reforms and the globalization of markets, perhaps triggered by innovations in information technology, may have also played a key role in the growing importance of knowledge workers. However, other lines of argument, such as changes in tastes and differences in trend labour productivity growth rates between industries, also offer possible explanations for such variations in the labour force composition over time.

4.1 An Employment Growth Decomposition Exercise

To help delineate the broad proximate causes of the changes in the share of knowledge workers in the economy, Lavoie and Roy (1998) use a growth accounting methodology to decompose the total change in the proportion of a given group of workers in total employment over time into three different components.

The first component is a skill *substitution effect* occurring within the production technology of domestic firms or industries. That is, for given levels of industry output and employment composition factors such as technological innovations or institutional reforms may favour a more intensive use of a given type of worker. For example, it is often claimed that the widespread diffusion of computer-based technology in the 1980s has led to a systemic substitution in the skill mix of the labour force favouring knowledge workers. The second source of change can be attributed to differences in labour productivity growth rates among industries (*the productivity lag effect*). That is, for a fixed proportion of industry output and unchanged occupational

structure, industries with stagnant labour productivity will require a growing fraction of total employment through time. Finally, the third component – *the output effect* – occurs when, for a given occupational structure and labour productivity by industry, shifts in the composition of final output of the domestic industry give rise to proportional changes in the structure of employment. For example, an increase in domestic final spending on products requiring a relatively large proportion of knowledge workers in their production (in the finance, insurance and real estate industry for example) will give rise to an increase in the proportion of knowledge workers in the economy.[9]

Table 2 presents the results from the decomposition exercise. Of the three effects, the substitution effect is the most dominant. It is extremely important especially for the knowledge and management categories of occupations over the whole period. Management and computer science workers, in particular, were both strongly affected over time by this component which tends to reflect their very pervasive expertise throughout the economy. It is fairly obvious that computer scientists have become an important source of expertise to deal with the increased complexity of problems related to the widespread diffusion of computer technologies. The intensification of global competition – in part brought about by the introduction of ICTs – may also explain the widespread need for managerial expertise.

Moreover, the importance of the substitution effect in explaining the growth of knowledge workers seems to be increasing over time. For example, between 1971 and 1981, the substitution effect accounted for about a third of their growth compared to 60 percent over the 1981-91 period.

The productivity lag component extensively influenced the growth of data and services workers. Despite the fact that a part of their activity is readily amenable to technological change, another portion – the tacit part – cannot be transformed by technology. The output component had a modest effect compared with the other two but was larger for data workers and, to a lesser extent, for knowledge workers, reflecting a shift towards data-intensive output and a weaker shift toward knowledge-intensive output.

[9] For complete details on the growth accounting methodology, see Lavoie and Roy (1998).

Table 2
Decomposition of the Change in Business Sector Employment Composition
1971-91

Categories		Substitution Effect	Productivity Lag Effect	Output Effect	Total Change*
Knowledge	1971-91	1.53	0.96	0.61	**3.10**
	1971-81	0.39	0.47	0.30	**1.16**
	1981-91	1.14	0.49	0.31	**1.93**
Pure Science	1971-91	0.02	0.01	0.01	**0.04**
	1971-81	-0.03	0.01	0.00	**-0.01**
	1981-91	0.05	0.00	0.00	**0.05**
Applied Science	1971-91	0.03	0.06	0.01	**0.10**
	1971-81	0.01	0.04	0.00	**0.05**
	1981-91	0.02	0.02	0.01	**0.05**
Engineering	1971-91	0.21	0.07	0.13	**0.41**
	1971-81	0.08	0.06	0.07	**0.21**
	1981-91	0.13	0.00	0.06	**0.20**
Computer	1971-91	0.76	0.06	0.09	**0.91**
	1971-81	0.21	0.02	0.03	**0.25**
	1981-91	0.55	0.04	0.06	**0.66**
SSHs	1971-91	0.51	0.76	0.37	**1.64**
	1971-81	0.12	0.33	0.21	**0.66**
	1981-91	0.39	0.42	0.17	**0.98**
Management	1971-91	7.81	0.37	-0.23	**7.96**
	1971-81	4.97	0.13	-0.06	**5.04**
	1981-91	2.85	0.24	-0.17	**2.92**
Sc-Technology	1971-91	0.88	-0.05	-0.01	**0.82**
	1971-81	0.65	-0.03	0.01	**0.64**
	1981-91	0.23	-0.03	-0.02	**0.18**
Other	1971-91	6.93	0.43	-0.22	**7.14**
	1971-81	4.31	0.15	-0.07	**4.40**
	1981-91	2.62	0.27	-0.15	**2.74**
Data	1971-91	-2.29	3.56	0.77	**2.03**
	1971-81	-1.83	2.25	0.35	**0.77**
	1981-91	-0.46	1.30	0.42	**1.26**
Services	1971-91	-1.58	3.72	-0.33	**1.81**
	1971-81	-0.93	1.92	-0.04	**0.95**
	1981-91	-0.65	1.79	-0.29	**0.86**
Goods	1971-91	-5.46	-3.55	-5.87	**-14.89**
	1971-81	-2.59	-2.28	-3.05	**-7.92**
	1981-91	-2.87	-1.27	-2.83	**-6.97**

* The total change in this table is based on total hours worked.
Source: Lavoie and Roy (1998)

The intensification of the substitution effect during the 1980s, particularly for knowledge workers, combined with the fact that their share has increased in all major industrial sectors, suggests that knowledge workers have now become essential in the production process of most industries. These findings suggest that technological change is a major force behind such occupational employment trends. However, the results are only suggestive of the role of science and technology and little is actually known about its impact on the structure of employment in Canada.

HRDC has therefore embarked on a research program aimed at developing a better understanding of the relationship between various types of technology or measures of technological change and occupational employment trends. For example, the program will investigate the impact of advanced manufacturing technologies such as robots and computer-aided design on the employment structure in the manufacturing sector. Another study will examine the impact of R&D investments (fundamental, development and applied research) on employment in all sectors of the economy, including the public sector. The international dimensions of technological change (e.g. foreign direct investment, foreign R&D, trade) and its impact on the employment structure also will be examined. Results from a first study by Lavoie and Therrien (1999) which focuses on the impact of investment in computers on the different categories of workers provides us with a first glance at the potential role of technology and are described below.

4.2 Employment Effects of Computerization

Computerization – the diffusion of a combination of hardware and software – has accelerated in the last 25 years due to advances in electronic technologies, the advent of the microprocessor and the tremendous development of the software industry. The process of codification has intensified and routinized tasks are disappearing, changing the structure of employment. The computer is increasingly associated with a number of occupations requiring highly skilled workers.

Lavoie and Therrien (1999) examine the impact of investments in computers at the industry level on the occupational structure of employment over the 1971-91 period. The authors assume that, computerization complements some categories of skills and replaces others depending on the

nature of tasks – that is tacit vs. codified and core vs. complementary.[10] Three hypotheses are tested:

i. The increasing use of computers is biased in favour of certain categories of workers. That is, computerization increases the proportion of certain categories of workers required per unit of output because it increases the complexity of certain tasks which are too tacit to be codified and which require the development of new skills (labour-using or complementarity bias).

ii. The increasing use of computers reduces the demand of certain categories of workers because their core and complementary tasks are codifiable (substitution bias).

iii. The computer has no effect because of the highly tacit nature of the tasks performed in certain occupations (neutral effect).[11]

In contrast to other similar studies which tend to divide the workforce into two broad skill categories (e.g. skilled vs. unskilled), the authors segment total employment into the nine categories of occupations described in section 3 above. This enables them to capture the diversity of possible relationships between computers and the different occupational categories. In addition, unlike most other studies which focus exclusively on the manufacturing sector, Lavoie and Therrien (1999) provide evidence on the primary, manufacturing and service sectors.[12] Only the results of the aggregate analysis will be presented here, however.

An examination of the magnitude of the regression coefficients presented in Table 3 reveals that in the 1970s, the impact of the computer on the employment structure was not significantly different from that of other types of physical capital. In the 1980s however, the impact of computers outweighed the effect of other capital reflecting the significant diffusion of computers from the mid-1980s onwards.

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[10] While the employment effects of computerization is worth assessing given their rapid diffusion, the authors acknowledge that its is only one of many factors. For example, technological change is not limited to computer technologies which may have a small effect relative to other types of capital in a given industry. Moreover, the complementarity between skills and computer technology may also be supplemented by supply-side factors, organizational change, increasing intensity of international trade, and the speed of structural adjustment.

[11] There is a fourth effect of computerization on employment that is not examined in the paper which is that the computer may not lead to a change in the number of workers in a particular occupation but may instead transform the skill content of an occupation by either "upskilling" or "deskilling" work along a number of dimensions.

Table 3
Employment Effect of Computerization

	Knowledge	Management	Data	Goods
Capital intensity	1.5061 **	0.2412	3.3895 **	-4.8594 **
Computer investment intensity (1971 and 1981)	1.1608**	0.2448 **	3.8560 **	-6.4636 **
Computer investment intensity (1986 and 1991)	2.5829 **	0.5433 **	5.6372 **	-10.025 **

Notes: Dependent variables are employment shares (x100) for the Knowledge, Management, Data, and Goods occupations. Capital intensity = Capital Stock / Value Added.
Computer investment intensity = Computer investment / Machinery & Equipment investment
Time and industry dummies are included. Relative wages (wages of knowledge, management, data and goods occupations relative to the wages of the service occupations) are also included.
Coefficients are produced by SUR estimation. Standard errors are heteroscedastic consistent.
See Lavoie and Therrien (1999) for a detailed description of the methodology and estimation results.

** Statistically significant at the 5% level.

The aggregate estimates show that there is an increasing complementarity between computer intensity and the knowledge, data and management categories of workers. For the knowledge workers, the computer is mainly a complementary tool supporting core activities. In contrast, computers are more central to the core activities of data workers but tend to change the content of their jobs, placing greater emphasis on tacit complementary tasks. Thus, for data workers there appears to be a shift in the content of their work from codifiable core tasks to tacit complementary tasks as a result of computerization.

Computerization has not had any effect on service workers given that their tasks are largely tacit and cannot yet be codified (e.g. barbers, child care workers). On the other hand, computerized equipment and goods workers were found to be substitutes, with the strength of this relationship increasing significantly during the 1980s compared to the 1970s. As a whole, however, the authors find that computerization is more of a labour-using process rather than a labour-saving one but that computerization itself is not sufficient to account for all employment effects of technology.

[12] The public sector is excluded from their analysis.

In answer to our second question, the evidence presented in this section suggests that technology is indeed playing a role in shaping the structure of employment in Canada. The results are also consistent with firm-level evidence which has shown a complementarity between the introduction of computer-based technology in firms and the use of more highly skilled workers (see for example, McMullen: 1996). While computer investment captures the general technology trend, future work using other technology variables will help to more fully capture the employment effects of technology and perhaps refine the impact of computerization.

5. Skills Requirements and the Skills of the Canadian Workforce

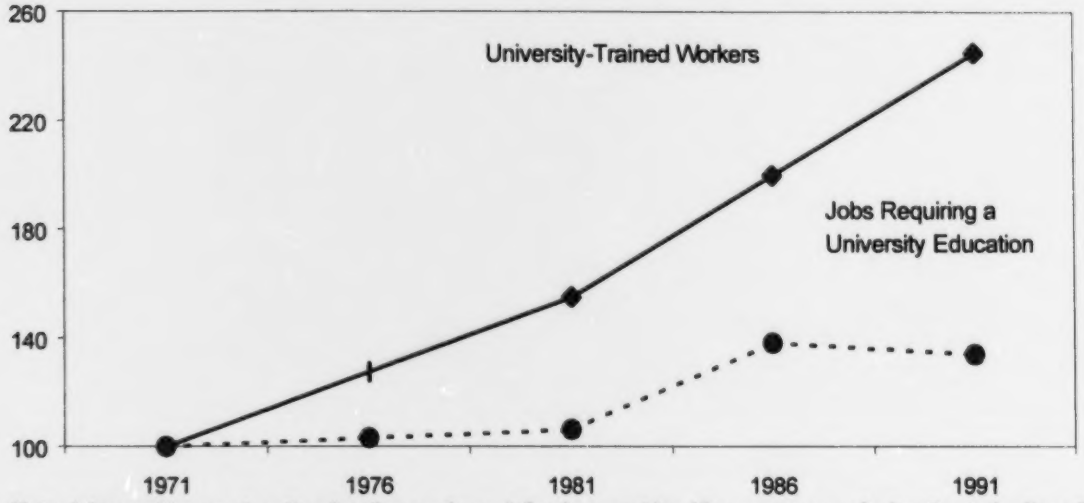
The final question to be addressed in the paper is whether, in the face of growing demand for knowledge workers, the skills of the Canadian workforce meet the requirements of the knowledge-based economy. Does the Canadian population provide a pool of skilled labour adequate to the needs of the economy? Is the Canadian labour supply comparable to that of other modern economies? Are we investing enough in the acquisition of skills? In a recent paper, Gingras and Roy (1998) examine a series of indicators to get at some of these issues.

As shown in section 3, university-level qualifications appear to be an important requirement to access knowledge occupations. Figure 10 compares the growth of jobs requiring a university degree with the growth in the number of university graduates between 1971 and 1991. The figure shows that the former grew by 40% while the latter grew by some 140% over that period. Thus the increase in the supply of university educated workers has far outstripped the growth in the economy's need for these qualifications and suggests that Canada may actually have a surplus of university-level skills.

It is, however, possible that the methodology underlying the data presented in Figure 10 overestimates the extent of the observed "oversupply" of university educated workers. For example, the level of skills required by today's jobs may have increased, in which case the assessment of needs may fall short. Indeed, we observe from a recent review of the literature and of some sector studies performed by HRDC that skill requirements have increased over time for several occupations (upskilling). There are also examples of jobs being deskilled. While it is difficult to be categorical, it appears that overall, there has been a slight increase in skill requirements within occupations.

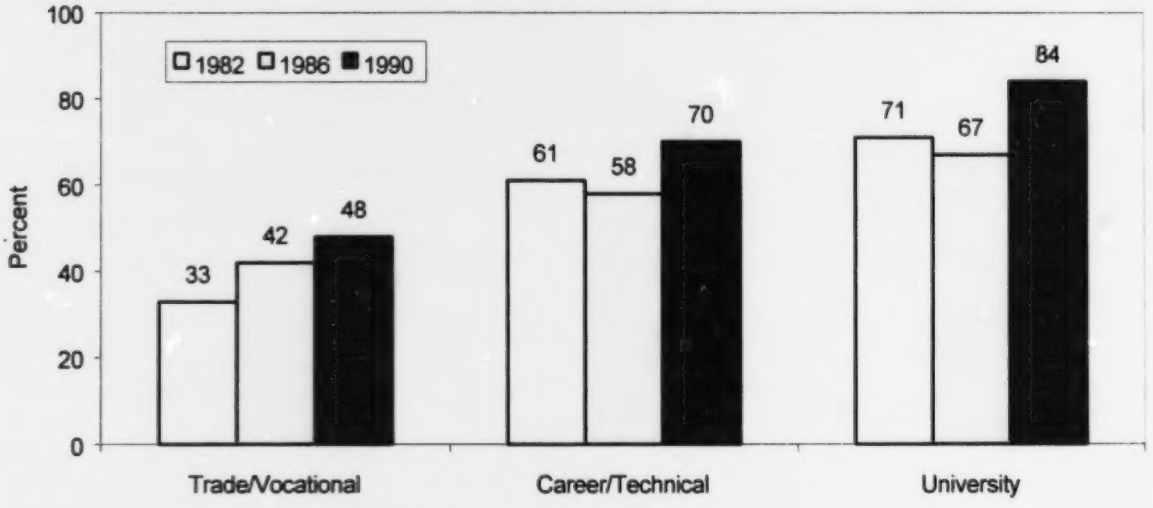
Evidence from the National Graduates Survey also suggests that the effective growth of demand for university graduates may be greater than is suggested by Figure 10. According to the survey, recent cohorts of university graduates are at least as satisfied with their job/education match as were earlier cohorts (Figure 11). If recent graduates were compelled to accept jobs for which they are overqualified, we would expect to see a deterioration in the match.

Figure 10
Demand and Supply of University-Trained Workers
1971=100



Note: Jobs requiring a university education are those defined as requiring 17 or more years of education in the Canadian Classification and Dictionary of Occupations
Source: Applied Research Branch, HRDC, using census data for 1971, 1981, 1986, 1991

Figure 11
Proportion of Graduates Whose Job Directly Matches their Training



Note: For graduates 2 years after their studies
Source: National Graduates Survey

It is also possible that the number of university diplomas awarded overstates the actual level of competence possessed by graduates. While the level of education can provide some indication of a person's skill levels, we need to recognize that education varies in quality and that individuals have different aptitudes. Thus for a given level of education, the skill level of individuals may vary.

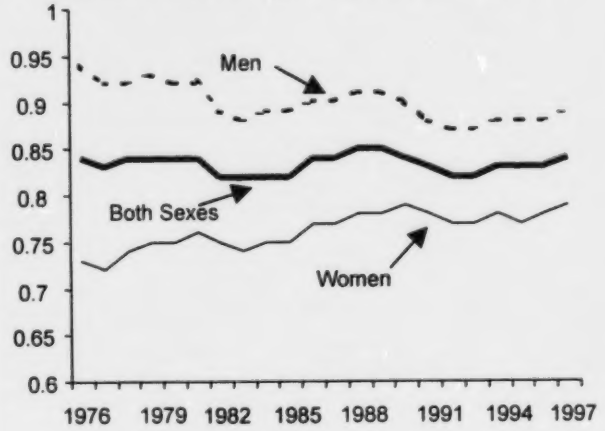
For example, the 1994 International Adult Literacy Survey indicated that 11% of university graduates in Canada had difficulty reading and interpreting texts. This variation in literacy skills within similarly educated groups may explain why some workers end up in jobs requiring less education than they possess. Indeed, Boothby (1999) finds that around 20 percent of university graduates were in a job which required lower educational qualifications and that those with lower than average literacy levels had a much higher probability of being in such a situation. Moreover, real earnings for these university graduates were much lower than for those whose level of education matched that required by their job. To some extent, the use of educational data could result in an overestimation of skill levels and thus the supply of skills would be lower than that shown in Figure 10.

While the apparent oversupply of skilled labour may not be as large as suggested in Figure 10, any true gap between the supply and demand for skilled labour would lead to increased differentials in labour market outcomes between high- and low-skilled individuals. In particular, an excess supply of skilled labour should lead to a fall in their relative wages. In the case of an economy-wide shortage of skilled labour, we should observe a relative rise in the wage premium paid to skilled workers. To the extent that wages are inflexible, we would expect the emergence of a gap between the supply and demand for skilled labour to be reflected in quantity adjustments (e.g. employment and participation rates).

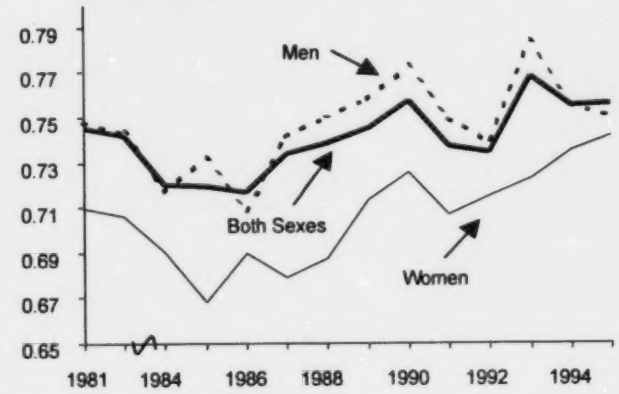
Boothby and Gingras (1998) examine trends in access to employment and the earning ability of individuals with post-secondary education (high-skilled) relative to those with less than post-secondary education (low-skilled) and find no evidence of a deterioration in the labour market conditions of the low-skilled workforce aged 20-54 over the last 20 years. As shown in Figure 12, the overall employment rate of low-skilled workers aged 20-54 shows no deterioration relative to that of high-skilled workers between 1971 and 1996. Access to employment for low-skilled women has actually improved while it has declined slightly for low-skilled men.

Figure 12

Employment Rate Ratios: Low- to High-Skilled Persons Aged 25-54,1976-1997



Weekly Earnings Ratios: Low- to High-Skilled Persons Aged 25-54,1976-1995



SCF data were not collected in 1983
Source: Boothby and Gingras (1998)

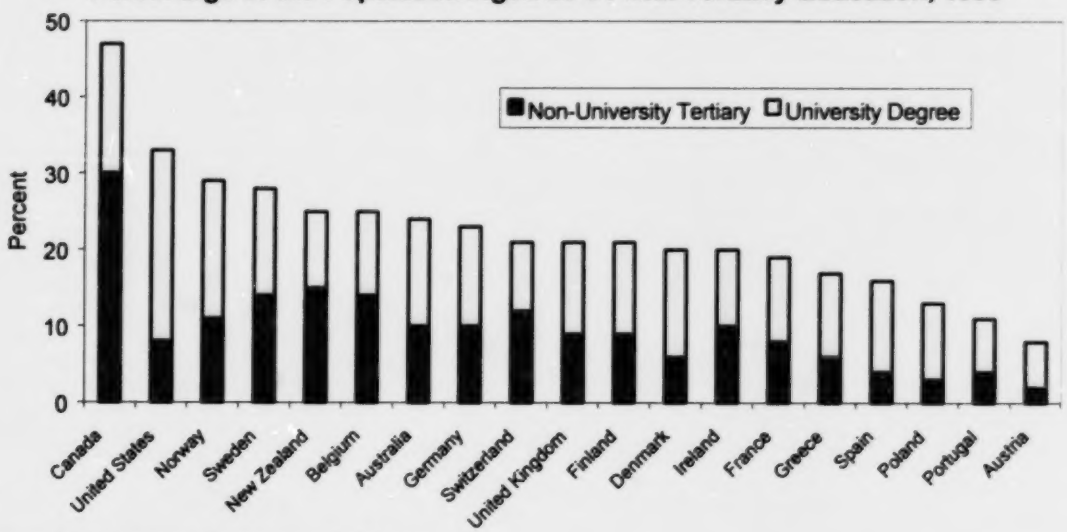
An examination of trends in relative earnings leads to a similar overall conclusion (Figure 12). Between 1981 and 1995, the ratio of average weekly earnings of low-skilled persons to the average weekly earnings of high-skilled persons actually shows a slight increase. Taken together, these trends suggest that, overall there has not been a shortfall of skilled labour in Canada.[13]

[13] For workers aged 55 and over, it can be demonstrated that the slight deterioration in the employment ratio for unskilled workers is primarily attributable to an age-composition effect. In this group, the average age of unskilled workers is considerably higher than that of skilled workers, and since the probability of being retired increases with age, we expect a deterioration of the employment rate of unskilled labour. This phenomenon is not, however, related to the level of expertise. The situation described above is slightly different for workers aged 55 and over. It can be shown that employment and earnings outcomes for low-skilled older workers have deteriorated somewhat relative to those of high-skilled older workers. However, much of this result is due to the fact that the least skilled – those with 0-8 years of education – are concentrated in this group and is not inconsistent with the view that there has not been a deterioration in labour market conditions for low-skilled older workers in general.

5.1 How do the Skills of the Canadian Workforce Compare to that of Other Countries?

While the evidence indicates that, in the aggregate, the skills of the Canadian labour force largely meet the requirements of the economy, an important question is how these skills compare to that of other countries. As shown in Figure 13, Canada counts among the countries having the highest stock of human capital in terms of educational level. According to OECD (1998), Canada led the industrialized nations in terms of the proportion of the population aged 25 to 64 having a tertiary education. In 1995, 47 percent of the Canadian population had a post-secondary education, while the corresponding number for the second-place United States was 33 percent. Canada also compares relatively well internationally in terms of average literacy attainment ranking fourth behind Sweden, the Netherlands and Germany on the document scale in 1994-95 (see Figure 14).[14] In general, the stock of skills of the Canadian labour force compare favourably to that of other industrialized countries.

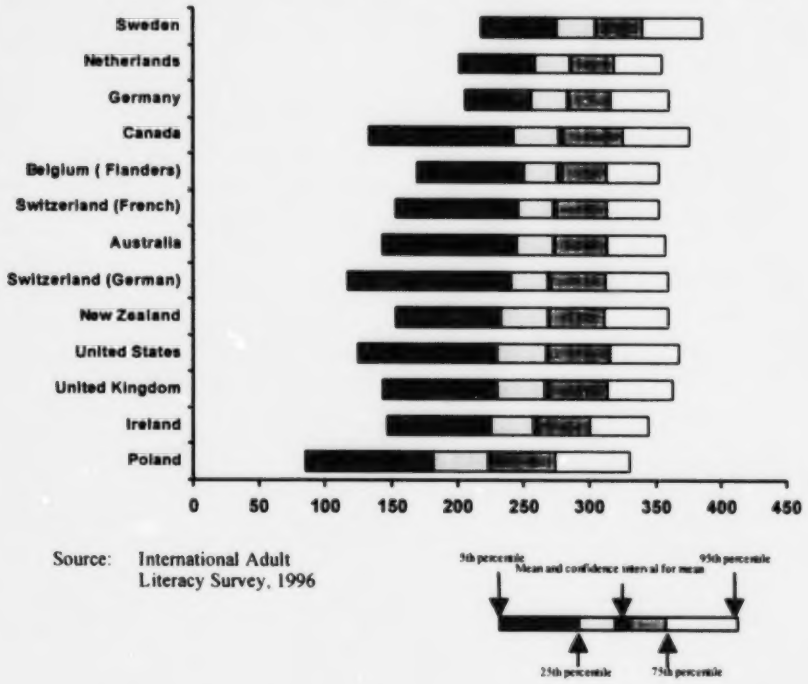
Figure 13
Percentage of the Population Aged 25-64 with Tertiairy Education, 1995



Source: OECD, Human Capital Investment, 1998

[14] Canada ranked third behind Sweden and the Netherlands on the prose literacy scale, while it ranked fifth on the quantitative scale behind Sweden, Germany, the Netherlands and Belgium (Flanders). See OECD (1997).

Figure 14
Scores on the Document Literacy Scale, 1994-1995



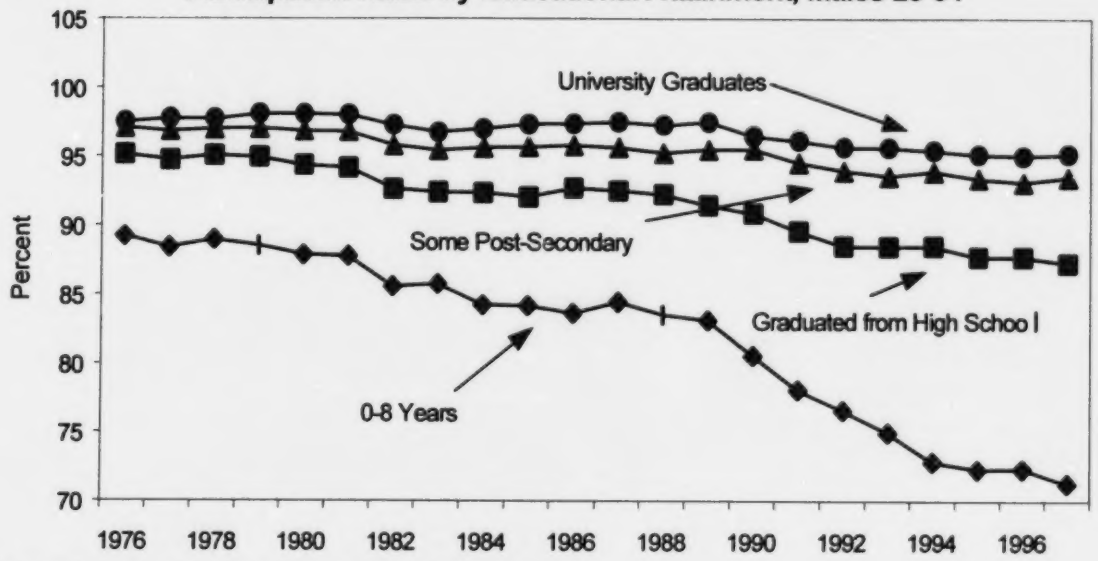
Source: International Adult Literacy Survey, 1996

5.2 Is There a Minimum of Skills Required to Succeed in the New Economy?

In economies where the average level of human capital is rising, and production activities are becoming increasingly complex, it is possible that some share of the least skilled segment of the labour force will have difficulty finding work and will eventually quit the job market. Several studies have found that older workers with less than eight years of education have seen their situation deteriorate substantially in recent years. In fact, this phenomenon is not restricted to older workers. As Boothby and Gingras (1998) show, the labour market situation of the least educated (those with zero to eight years of schooling) is worsening for most age groups in Canada (Figure 15). Older workers in particular are more vulnerable because the poorly educated are concentrated in this group. This age-related bias in the distribution of skills is also apparent when we look at levels of literacy (Figure 16).[15]

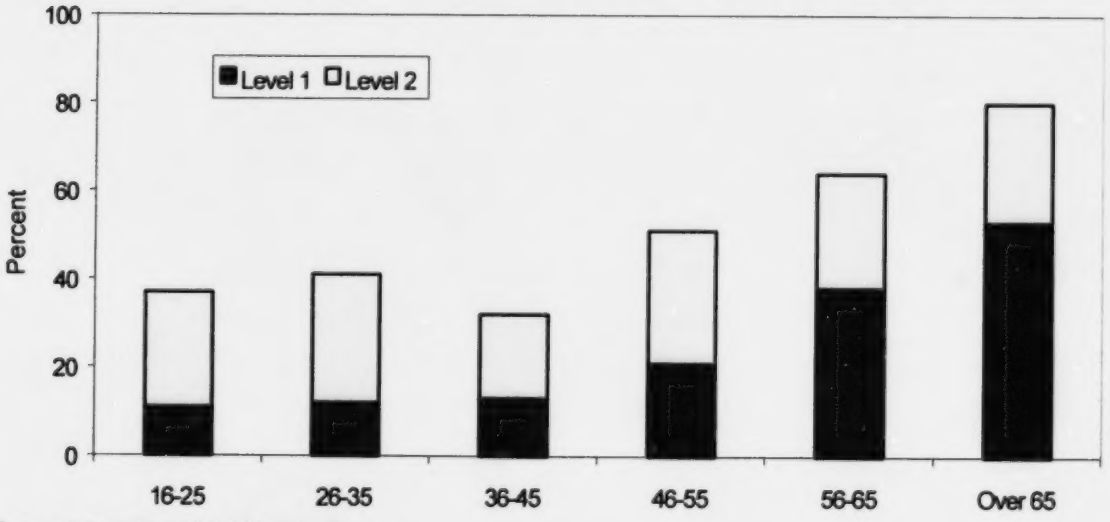
[15] In Canada, concerns over low literacy attainment extend beyond its impact on the labour market performance of selected vulnerable groups to inequality more generally. While Canada ranks well in terms of average literacy levels, the distribution of literacy skills in Canada is much broader than the other leading countries with relatively large numbers in both the highest and lowest literacy levels. Moreover, despite the high literacy levels recorded among youth, the literacy profile of the Canadian population is not expected to change by much in the next 30 years

Figure 15
Participation Rates by Educational Attainment, Males 20-54



Source: Special tabulations from the Labour Force Survey

Figure 16
Percentage of the Population with Low-Level Literacy Skills

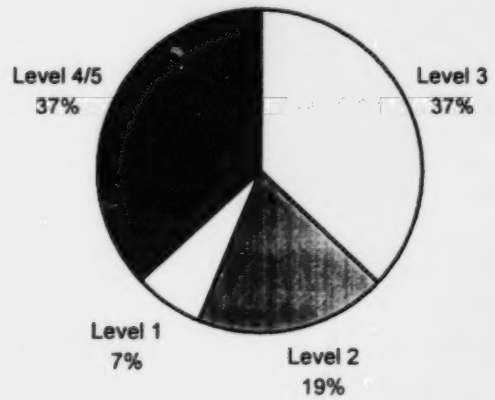


Source: International Adult Literacy Survey

as a result of population ageing and increased reliance on immigration as a source of population growth – literacy proficiency tends decline with age and is lower among immigrants. In a context where the demand for literacy skills is increasing, this finding suggests that literacy may be a source of polarization in the future.

The phenomenon of the least qualified workers being shut out of the labour market suggests that there is a minimal level of competence required to land a rewarding job in Canada. According to HRDC's Essential Skills Project, the literacy requirements of the lowest skilled jobs are clustered around level three. As Figure 17 indicates, nearly 75% of young Canadians between 16 and 25 possessing a high school diploma have attained level three or better. The remainder are at level one and two and face a reduced choice of jobs and lower earnings. Moreover, the IALS shows that persons with low levels of literacy skills are less likely to have access to adult education and training opportunities. The Canadian job market thus offers little to youths that do not have a high school diploma.

Figure 17
Distribution of Literacy Attainment for Youths with a High School Diploma, Aged 16 to 25



Source: International Adult Literacy Survey

6. Conclusion

This paper sought to provide a brief synthesis of some of the main findings of recent HRDC research on the changing skill structure of employment in Canada. Three questions were addressed:

i. How has the skill structure of employment evolved in Canada?

ii. What has been the role of technological change in the changing structure of employment?

iii. Do the skills of the Canadian workforce meet the requirements of the knowledge-based economy?

With respect to the first question, we can say that on the whole, the Canadian economy is becoming increasingly knowledge-based. The knowledge and management categories of occupations have been increasing rapidly, and although their overall share of total employment remains small, they are increasingly essential to the production process of most industries. These occupations require high levels of education and literacy skills. They also place greater emphasis on cognitive and communication skills than most other occupations. In fact, as a general rule, employment in occupations which require high levels of cognitive and communications skills has increased faster than in other occupations. These are some of the skill dimensions that are increasingly emphasized in most definitions of a knowledge-based economy.

As for the second question, our research suggests that technological change is a major driving force behind occupational employment trends we are observing, particularly beginning in the second half of the 1980s. The growth decomposition analysis has shown that the substitution effect is dominant in explaining the widespread growth of knowledge and management occupations. The analysis of the employment effects of computerization show that in general, there is an increasing complementarity between computer intensity and the growth of the knowledge, data and management categories of workers. However, it is worth emphasizing that computerization has different effects depending on the occupation, complementing some categories of skills and replacing others depending on the nature of tasks – that is tacit vs. codified and core vs. complementary.

While computer investment captures the general technology trend, future work using other technology variables will help to more fully capture the employment effects of technology and perhaps refine the impact of computerization. Further research is also required to assess the impact of other factors which may have influenced the employment structure in Canada (e.g. organizational change, institutional change, international trade). One important area concerns the relationship between technological and organizational change and changes in the skill structure of employment and the nature of work. Future work in this area will focus on data from the new Workplace and Employee Survey (WES) which is an innovative survey that links information on workplaces such as the adoption of technology, organizational change, training and other human resource practices to information on employees in those workplaces such as their wages, hours of work, job type and skills. It is hoped, that through time, the WES will provide us with a better understanding of how technology and organizational change affects skill requirements and how changes at the micro level are reflected in changes in the aggregate economy.

The final question that was addressed in the paper is whether the Canadian labour force possesses the skills to meet the changing requirements of the economy. Our analysis of various indicators suggests that Canada is not suffering from a broad-based shortage of skilled labour. We do not observe any significant deterioration in the labour market situation of low-skilled workers relative to those of high-skilled workers. Overall, the supply of highly educated individuals appears to have more than offset increases in demand. In fact, Canada compares favourably with most of its principal trade competitors in world markets in terms of the stock of skills.

While the skills of the Canadian population appear to be adequate overall, we must be cognizant that they are not evenly distributed and that certain segments may be at risk of exclusion. As we have shown, the economy is increasingly demanding in terms of minimal skill requirements and it appears that a high school diploma is now required to gain access to stable jobs and income. In this context, greater efforts to encourage youth to finish high school are warranted.

However, as emphasized in this paper, education is but one dimension of skill. The development of new measures of skills, competencies and aptitudes is crucial to gaining a better understanding of which attributes are important in a knowledge-based economy and how they contribute to labour market success. The International Adult Literacy Survey and the work by Boothby (1999)

and Béjaoui (1999) summarized above have advanced the state of knowledge in this respect. Next steps in this area will focus on the OECD International Life Skills Survey (ILSS), sponsored by HRDC and Statistics Canada. This survey will build on the IALS by developing and testing a number of basic skills: numeracy, prose and document literacy, teamwork, problem solving, and information technology. In sum, establishing which skills are quantitatively important is essential if public policy is to effectively address the issue of how to foster their acquisition, development and maintenance throughout life.

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